MIDDLETON

An Investigation of
the Gasoline Mine Motor

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AN INVESTIGATION OF THE GASOLINE MINE MOTOR

BY

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TABLE OF CONTENTS.

CHAPTER I

TABLE OF CONTENTS.

CHAPTER I

CHAPTER I.

BRIEF HISTORY OF THE EARLY METHOD

OF HANDLING ORE.

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Before taking up the gasoline mine motor it may be interesting
to examine some of the early methods of transporting ore. It is hard
to conceive that an industry that uses such modern machinery as is
found in mines and quarries today was once carried on without any
machines, and that the product of the miners was conveyed to the
mills on the backs of women and children. But such are the facts,
as recorded by the early historians, although there is a missing
link between the past and the present that can be only surmised.
Just how the Egyptians built their pyramids we do not know. They
left no records of how those great blocks of syenite were quarried
and placed in position, in many cases several hundred feet above the
level of the plane. We do know that the engineers of today could
not do work of this gigantic nature without constructing elaborate
machinery such as was not at the command of the builders of these
immense tombs. A common assumption is that they dragged the stones
on rollers from a nearby quarry and placed them in position by brute
strength. The nearest approach to this crude method of transporta-
tion that is found in modern practice is at the Carrarro stone
quarries of Italy, where blocks of marble are rolled down the side
of the mountain to a place where they can be skieed onto cars.

In 1842 commissioners were appointed in England to look into
the matter of female labor in mines. They reported that women

worked from twelve to fourteen hours a day in foul, unsanitary places, crawling where coal beds were thin and dragging loaded cars along roadways that were sometimes covered with a foot or more of mud and water. It was customary for women of Scotland, in the early days, to carry coal in baskets on their backs. The tanatero, or bag-carrier, may be still seen in Mexico, but women are not allowed to work in the mines. In some mines of Central America the palanquin is used. It consists of a box with two parallel strips about eight feet long, fastened to the sides in such a manner that they may be used as handles. The burden is carried by two men walking single file and supporting the load midway between them.

In India it is customary to carry ore in a basket supported on the head of the carrier. He climbs vine ladders with his burden and takes it to the sorting place. In many places the natives object strenuously to any change in the system of transporting ore. They have the mistaken idea that any plan whereby one man accomplishes the work previously done by five or six, is bad, even though he does the work with a lesser amount of exertion to himself than he had expended by the old method. They contend that these displaced men are thrown out of employment and they are not farsighted enough to realize that any increased efficiency means greater production and, therefore, work for a larger number of men. They look upon the invention of modern transportation machinery in the same light as did the farm hands who burned so many of the first grain reapers that were introduced into the harvest field.

Before cars or wagons came into use in the mines of England it was the custom to drag the coal in "tubs", as they were called. In many places the roof was not over two and a half, or three feet

above the floor, and two women crawling on their knees were employed to "put" the tub. The leader of the squad wore a heavy belt to which was attached a chain which passed back between her legs and hooked to the tub. The second woman crawled behind and pushed. These tubs were later improved by the addition of wheels and were then called wagons, but the means of locomotion remained the same until about 1842 when a law was passed forbidding women to work in mines.

The wheel-barrow had its turn underground and is still used on rare occasions, but it has been very generally discarded on account of the high cost of transportation by this method. Two wheeled carts were used, first on the bare floors and later on a plank road- way. This gave trouble owing to the fact that the planks were prone to split and curl up at the ends. They were sometimes laid cross- wise in the manner in which a lumberman builds a corduroy road but this, of course, was far from economical.

The next step in the improvement of underground conveyance of ore was the introduction of metal plates, in 1803. These were fas- tened on the tops of planks and were deemed a great boon to under- ground haulage. It seems, however, that no great interest was taken in the improvement of these underground conditions until women were forbidden to work in the mines and men were forced to do this un- pleasant labor. From the metal plates it was a comparatively short step to the light weight rail that is spiked to cross ties. The size of mine cars has increased and the rail has had to be made larger accordingly, to support the heavier load. A rail lighter than 20 pounds per yard bends between ties and is hard to keep in

alignment. Rails in up-to-date mines are usually in the neighbor-
hood of **40** pounds to the yard.

As mines increased in size and women were denied the privilege
of slaving underground, ponies were introduced in the English mines
to increase the output and to diminish the cost per ton. As the
tide of progress has advanced these in turn have given way to the
various forms of mechanical haulage in order that overhead expenses
may be reduced to a minimum. It is only in short hauls, or in
mines of small output, that animals can compete with a mechanical
haulage system.

In 1852 Overman wrote an article saying that the dog cart was
in general use in our Western mines at that time and was a very
convenient method of hauling coal. His description of the cart
states that it was made **three** feet high with light wheels and had a
capacity of twelve **bushels**, or one-half ton of bituminous coal, and
was shaped like a **furnace** barrow. The dog was hitched to the front
of the cart and a man guided the vehicle by means of two handles
projecting to the rear. On a plank road the dog could easily pull
the entire load and the man had only to steer the cart. Upon reach-
ing the dump the dog would turn aside and the man would raise the
handles to discharge the coal. By means of this scheme the man and
dog did the work of two men in hauling a half ton of coal. In 1909
a small mine in Illinois was employing no less than thirty-one dogs
in this manner, and had been using dogs for many years. It is said
that twenty thousand dogs were taken into the Klondike in one year
for use as draft animals.

Another very useful animal used in mine haulage is the burro.
He is an all-purpose carrier, his burdens ranging from mining mach-

inery to prospectors' equipment. Burros are capable of carrying 200 pounds of freight over paths and roadways which horses cannot travel. They are not expensive animals and as a general rule obtain their feed by foraging.

In South America the llama is drafted for mine haulage and is considered well adapted to this use.

In the United States the mule is the most popular animal for mine work. His low stature makes him more useful than a horse for low coal, and there are a number of reasons why he is more desirable in underground work. He requires less feed, keeps in better condition, is tougher, learns more easily and uses more judgment in his work. Mules are used singly or in teams of from two to four driven in single file. Empty cars are drawn to the rooms by the mules and loaded ones returned to the parting where the trip, or train, of cars is made up. Under certain conditions, where the output does not exceed 400 tons daily, mule haulage is usually as economical as any system, provided the haul is not over one-half mile.

Another type of haulage is the gravity plane. Frequently mines are located above the water-level, with their openings on hillsides which are too steep to be reached by any of the methods heretofore described. When a case of this kind is encountered the gravity plane is an easy way out of the difficulty. The principle of the system is that a loaded car attached to a rope in moving down the incline is acted upon by gravity to such an extent as to enable it to draw up an empty car attached to the other end of the rope. On long inclines the weight and friction of the rope must be considered in the design of the plane, but gravity planes are so well

known to mining men that it is scarcely worth while to go into details of their design, in this article. A slight variation of this system is met with when the grade is not sufficient *for gravity* to draw up the empty cars and power must be supplied for this purpose. The **sys-tem** is then termed an engine plane.

A very similar method of drawing loads up an inclined plane and returning the empties is by means of the chain haul. A double track is installed and along the middle of each track, a chain moves at a uniform rate of speed. The cars are pushed on the foot of the incline and automatically, *their axles are engaged* with spurs on the chain and are automatically released upon arriving at the landing. Empties returning on the other track are treated in the reverse order. The chain controls their downward passage and deposits them in safety at the bottom. This system is especially adapted to short hauls. On longer hauls a cable is used instead of a chain, but it is not so convenient in its operation owing to the fact that a grip must be used to secure the cars to the cable.

The aerial tramway has also been used to some extent. It consists of a bucket suspended beneath a cable by means of a two wheel carrier. On steep inclines the movement of the bucket is controlled by means of a rope attached to the bucket and wound on a drum which is equipped with a brake. For short distances it is drawn back by hand, or the drum may be equipped with power. The bucket is filled by a chute from the stope and dumps by turning over on its journal supports at the end.

The mono-rail system is very similar but is more elaborate and is designed for greater capacity. A larger bucket is used and the support is a light weight steel rail suspended from the roof at

regular intervals. This allows of switching from one track to an-
other by moving switch points as is done on a tramcar track on the
ground. Where the track is comparatively level the bucket may be
pushed by hand but on steep slopes a cable is necessary.

Bucket conveyors and belt conveyors were introduced shortly
after the chain haul system. Both are so commonly used that a de-
scription of either is superfluous. The bucket conveyor is made in
a great variety of sizes, and capacities vary greatly, but five hun-
dred tons an hour is not uncommon. The belt conveyor also varies
in capacity, owing to the various widths of belt used, but ranges as
high as twelve hundred tons an hour, or more. The latter conveyor
has great flexibility and is practically noiseless.

Pan conveyors have been used for sorting tables, as has also
the traveling table. These conveyors are used for short distances
only.

I shall now discuss very briefly a very important system of
haulage, namely, the rope haulage system. This system is divided
into two types, the endless and the tail rope systems.

The endless rope haulage system, as its name implies, is one in
which the rope travels continuously in the same direction, passing
from the drums to a deflecting sheave at the extremity of the system
and back again to the drums. The drums are connected
and driven in tandem. To take care of the varying lengths of rope,
due to stretching and to temperature variations, it passes from the
drumsback to and loops around an auxiliary sheave mounted upon trucks
and attached to a tension rope which takes up, or plays out, slack
as the haulage rope expands or contracts. By this means the tension

in the haulage rope is kept uniform. Cars are attached to the rope
by means of grips, of which there are a great variety in use. Two
tracks are used, one for the outgoing loads and one for the return-
ing empties. Since the rope travels continuously the speed must
necessarily be slow in order that cars may be attached and released,
and consequently four miles an hour is about the maximum.

The tail rope system differs from the endless rope system in
that the rope does not travel continuously in the same direction,
and two ropes, instead of one, are used--one for drawing in the loads
and, one for returning the empties. The cars are handled in trains, or
trips, on a single track roadway. The tail rope passes around a
sheave at the parting and couples to the rear of the train. The
main haulage rope is attached to the front car and as the train is
hauled in the tailrope unwinds from its drum and follows. Upon
reaching the bottom the ends of the rope are transferred to a string
of empties, the power transferred to the tail rope drum and the emp-
ty trip drawn to the face, with the main haulage rope dragging
along behind. The speed is greater in this system than in the one
previously described, often running as high as twelve miles an hour.

Many   of the foregoing methods of transporting ore
are more or less obsolete and are of interest to the modern engi-
neer only as a matter of history. True, many of them are in use
today but their use is limited to small mines or to places where
conditions do not permit of the most up-to-date machinery. In the
next chapter I shall take up the discussion of the more modern types
of mechanical haulage such as are used by scientific operators who
consider haulage from the standpoint of economy and efficiency.

CHAPTER II.

MODERN TYPE OF MECHANICAL HAULAGE.

* * * * * *

Among the modern types of mechanical haulage are found four systems, which named in order of their adoption for use in mine haulage, are as follows: Steam, compressed air, electric and gaso-line locomotives.

Six-Wheel-Connected Steam Mine Locomotive, Class C-Mine

Wide or Narrow Gauge

ILLUSTRATION No. 28, from photograph of 10 x 16 cylinders locomotive, 36 inches gauge of track, 6 ft. height.

The steam locomotives used in mines are similar in construction and operation to the railway locomotive. They differ in size and design to meet the requirements of underground work. Their height over all must be about fourteen inches less than the minimum clear-ance between floor and roof. This is distributed as follows: six inches for ties, four inches for rail and four inches for clearance. Where possible, a great er amount of clearance should be allowed. The dimensions of a locomotive vary with weight and capacity, but as an example take a 14 ton motor. This machine stands about 5' 6" above

the rail, has a wheel base of 4' 6", 30" drive wheel; 10"x 14"
cylinders will round a curve of 16' radius although it should not be
used on such sharp curves, and has a tractive power of about 6000 lbs.
These figures are merely comparative, as the designs of mine locomo-
tives vary greatly to meet the requirements of the place in which
they are to be used.

Steam locomotives are not considered to be desirable in gaseous
mines, although there are no records to show that a mine explosion
has ever resulted from their use. It is not practicable to fire them
with soft coal underground on account of the smoke and suffocating
gases emitted. For this reason steam locomotives for underground use
are restricted to drift mines. The engine is designed to make a
trip of four to seven miles without firing. This enables the engine
to go in to the parting and return with its load without any fresh
fuel being added to the fire. When used in this manner the steam
locomotive is probably as satisfactory and more economical than any
other form of haulage. The fact that it is not suitable for closed
mine work has called for other forms of mechanical haulage.

The compressed air locomotive is especially adapted to closed
mine service. There is absolutely no danger from fire with use of
compressed air as motive power. It emits no smoke or other undesir-
able gases, but on the other hand it gives forth wholesome air which
is of great value in ore mines where the ventilation is not good.

The mechanism of an air locomotive is similar to that of a
steam locomotive, but instead of a fire-box and boiler to generate
power it is equipped with storage tanks in which a supply of air
is charged at a pressure of about 800 lbs. per square inch.
The air passes from the storage tanks to an auxiliary tank before

it enters the cylinder. By means of an automatic reducing valve
and stop valve the pressure in the auxiliary reservoir is adjusted
to the working pressure of the motor which is usually from 125 to
150 lbs. per square inch.   The storage tanks receive air at the
charging station through a filling pipe fitted with couplings and
flexible joints.   There are two methods used in charging the locomo-
tive; it may be charged direct from the compressor or from a reser-
voir.   The former method requires a larger compressor and also
takes a very much greater length of time. Unless the intervals
between hauls are long, charging from the reservoir is more economi-
cal. The latter method allows the compressor to work continually
and hence a smaller machine may be used. A locomotive may be
charged from a reservoir in about two or three minutes. The reser-
voir may consist of a storage tank or a pipe line. The latter is
the more common practice in mines because the air may be carried to
any part of the mine and charging stations may be installed at the
most convenient places.
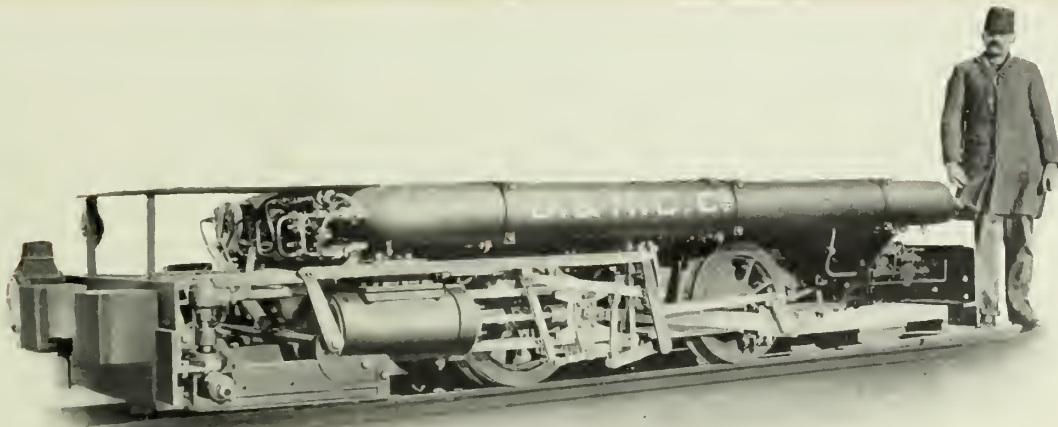
O-4-O-TYPE
FOUR WHEEL COMPRESSED AIR LOCOMOTIVE
FOR MINE SERVICE WHERE HEADROOM IS VERY LIMITED

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Diameter of cylinders..........................7 in.
Stroke of piston..............................14 in.
Diameter of driving wheels....................24 in.
Total wheel base.........................4 ft. 3 in.
Total length............................12 ft. 3 in.
Total height.............................2 ft.11 in.
Total width..............................5 ft. 4 in.
Storage capacity for air.....................40 cu. ft.
Storage pressure...................700 lbs. per sq. in.
Auxiliary and working pressure....125 lbs. per sq. in.
Weight..................................12,600 lbs.
Tractive power...........................3,050 lbs.
```

The foregoing cut and general dimensions of one of the air locomotives manufactured by one of the leading companies in that business, give an idea of the adaptability of a motor of this type for mine work.

The electric locomotive has been an important factor in the economics of mine haulage and its inherent advantages have been demonstrated by many years of successful service. The first electric locomotive was built in 1887 for the Lykens Valley Colliery of the Pennsylvania R. R. Company. This "Pioneer", as it was called, was a great success but it bore small resemblance in outward appearances to an up-to-date motor.

The foregoing cut shows one of the Jeffrey Company's latest models in electric mine locomotives.

An electric mine motor in its strictest sense consists of a heavy rectangular castiron framework carried on two or three pairs of drive wheels that are driven by series motors of the railway type through single reduction gears. An iron bracket, cast or bolted to each motor frame, is fitted with bearings in which an axle runs, thus supporting one side of the motor; the other side is suspended from the frame of the locomotive by springs so as to reduce the jarring caused by uneven tracks. The motors are operated by means of one or two controllers on each locomotive. The electric current is transmitted from the power house to the motor by means of a copper trolley wire which is suspended from the roof of the mine at regular intervals. As the current leaves the trolley wire to enter the locomotive the first part it passes through is the trolley wheel, which is a small groved metal wheel about four inches in diameter and bushed with an anti-friction bearing, revolving on a hardened steel pin. This in turn is carried by a trolley harp mounted on the end of a wooden trolley pole swiveling in a socket on the frame of the locomotive. The trolley pole is actuated by a spring which holds the trolley in contact with the wire. Current is conducted from the trolley harp by a flexible cable to a protective device in the nature of a fuse or circuit breaker and thence to the controller. The controller consists of a cylindrical switch for varying resistance of the motor circuit, and of a reversing switch for reversing the direction of the current through the armatures, or fields, in order to reverse the locomotive. A switch for throwing the motors

into either parallel or series connection may be incorporated in
the reverse switch. Series-parallel controllers such as are used
in street railway practice are not found practicable for mine work
because the starting effort is usually the maximum load. With the
motors in series, if one pair of wheels slips the counter electro-
motive force generated by this motor due to its increased speed,
limits the current passing, reduces the torque of the remaining
motor and leaves small torque to start the train. With motors in
parallel the slipping of one pair of drivers has no effect on the
others. In handling empties and in switching, the series connection
is an advantage in avoiding the constant or excessive use of re-
sistance points. From the controller the current flows through the
resistance which is placed in the circuit to regulate the starting
speed of the motor. The current then passes to the reverse and
series switch, which usually consists of a wooden cylinder inside
of the controller case to which are fitted copper segments so ar-
ranged that the contact brushes, which are the terminals of the
motor leads, are connected to give the proper rotation of armatures
and the proper path for the current through the armatures and fields.
Current is delivered to the armatures through carbon brushes which
are held in contact with the commutators by springs. The current
after flowing through the windings of the armatures and field coils
enter the frame of the motors and then passes through the axles and
wheels to the rails and return circuit to the power house. To in-
sure a good return circuit it is necessary to bond the rails with
copper conductors. This is done to reduce the track resistance and
keep down transmission losses.

The ever increasing demand for mechanical haulage have brought about the birth of the gasoline motor. The gasoline motor has been used in America only a short time but has shown itself remarkably well adapted to mining service. The first gasoline mine locomotive used in America was installed at the Midvalley Coal *in May 1910, and is still in active service.* Company mines at Wilburton, Pennsylvania, Its speed ranges from three miles per hour on low gear to six miles per hour on high. Mr. H. D. Kortenbander, Superintendent of the mine, states that it replaced five mules and one steam locomotive, uses an average of twenty gallons of naptha per day of ten hours, works very satisfactorily and that it is considered very cheap haulage. Consular reports indicate that about two thousand gasoline motors are in use in European mines. Nearly six hundred are used in America at the present time. This is ample proof that the gasoline mine motor is well past the experimental stage and is rapidly gaining favor among mining men.

The figure shown below is taken from a photograph of a 5 ton locomotive made by the Milwaukee Locomotive Manufacturing Company. This machine has an overall length of 115 in. and is 46 in. high; its width varies from 43 in. on a 35 in. track to 51 in. on a 44 in. track; the wheel base is 45 in. and wheel diameter 18 in.

The essential parts of the locomotive are the castiron frame, mounted on four wheels, and the gasoline engine which generates the power to drive the machine. A description of the frame is scarcely necessary as the figure last shown and the one below show very clearly its heavy, rugged construction. Let us then discuss the design of the engine.
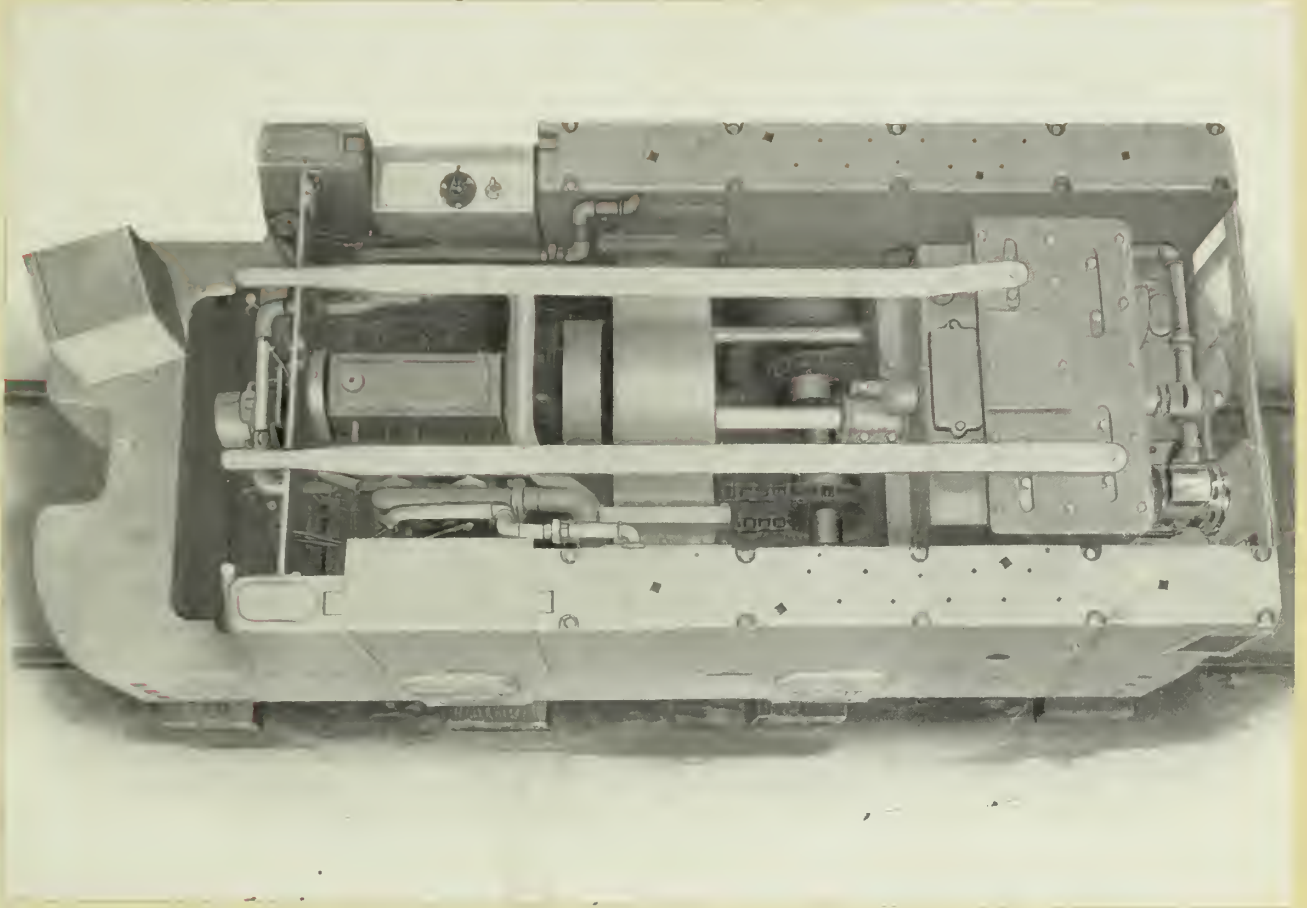
The engine used in the gasoline locomotive is of the ordinary marine, or automobile type, having four cylinders, four cycles, electric spark plug ignition and is governed by means of regulating the point of ignition and the amount of gasoline used. The gasoline used for fuel is carried in two removable tanks which are connected to the carburetor with copper tubing and suitable fittings, and

are provided with safety stop valves which seal the tanks and pre-
vent any loss of fuel when the locomotive is^not in use, and when the
tanks are removed for filling. The tanks are made removable so
that they can be filled outside the mine. They are well protected
when in place in the locomotive, by the heavy framework of the
machine.

Both horizontal and vertical engines are used in mine service.
The Whitcomb Company uses the former type and the Milwaukee Company
uses the latter. So far as actual operation is concerned there is
practically no difference between the two. The vertical engine is
easier to lubricate,as the splash system of oiling can be used, but
on the other hand the vertical engine increases the height of the
locomotive to such an extent as to prohibit its use in thin coal
beds.

A very important part of the gas engine is the carburetor.
Before the fuel can be used in the cylinder of engine it must be
vaporized and mixed with the proper proportion of air to make an
explosive mixture, and this is the function of the carburetor.
All forms of carburetors or vaporizers to properly perform their
duties must have means of regulating the fuel and air supply. The
gasoline flows to the carburetor by gravity and is admitted to a
chamber by means of a float feed which keeps the fuel at a constant
level in this chamber. From the float chamber the gasoline passes
through a nozzle and is sprayed into a current of air which is
drawn through the carburetor by the suction stroke of the engine.
It is often the case that the carbureted air leaving the carburetor
is too rich in gasoline vapor for complete combustion and it be-
comes necessary to mix it with additional air. A secondary air

supply is arranged to take care of this condition. By opening a
valve, atmospheric air is drawn in by the suction stroke and this
fresh air is mixed with the carbureted air. Any degree of richness
may be obtained by regulating this last mentioned valve. The by-
passing of air through the secondary air-inlet is necessary in
engines of varying speed, in order to overcome the tendency of the
suction spray nozzle to supply an excess of fuel at high speed, when
the vacuum in the mixing chamber is high. Any change in the humidity
or in the temperature of the air calls for further regulation of
the carburetor.

     After the air has been properly carbureted and drawn into the
cylinder it must be ignited. The modern method of igniting the
charge is by means of an electric spark. The requisite current may
be obtained in various ways; by means of a common cell battery, by
storage battery, from an electric service circuit, or by means of a
small special dynamo or induction magneto. The electric spark is
formed in two ways, by the so-called jump-spark system, and by the
make-and-break system. In the former system there is provided, in
the secondary circuit from an induction coil, a gap between two
sparking points in the cylinder. When thus the primary circuit, in
series with the battery, is opened or closed, a spark will be formed
between the sparking points--it, so to speak, jumping across the
gap between the points, thus giving name to the system.   In the
jump-spark system the current must be of high tension to cause a
spark to form between the sparking points; these generally being set
1/32 to 1/16 of an inch apart. In the make-and-break system the
sparking points are in contact before the time for a spark. When
the circuit then is broken, suddenly, by moving apart the contact

points, a good spark will be formed with a current of less tension than that required in the jump-spark system, and the deterioration of the sparking point will be less.   The primary wire of an induction coil is often inserted in the circuit in order to intensify the spark.

The type of engine used on the gasoline locomotive is fitted with the float feed carbureter and the jump-spark system of ignition.   The electric current for the spark is furnished by batteries for starting the machine and by a magneto when the motor is running.

The writer was unable to obtain satisfactory data on the early history of the American gasoline locomotive.   According to Professor H. H. Stoek there were a few machines turned out in the early part of the present century which met with little success.   The Prouty Company of Detroit installed one in Kentucky and advertised their machines extensively in mining journals, but apparently they soon gave up the idea of manufacturing gasoline locomotives.   The Fairbanks-Morse Company of New York did some experimenting along this line about that time, but did not put any machines on the market.

CHAPTER III.

COMPARATIVE COSTS OF INSTALLATION AND OPERATION OF
GASOLINE, ELECTRIC AND MULE HAULAGE SYSTEMS.

* * * * * *

In order to make an absolutely true comparison of the gasoline, electric and mule haulage systems it would be necessary to try out the three methods in some mine. This is not possible at the present time but mines have been chosen in the same district where conditions are fairly uniform. The ton-milage per ton of motor and per mule has been obtained from the daybooks of fourteen mines in one district in Illinois. Eleven of these mines use electric motors, two use gasoline motors and one mules, for the main haulage. All use mules for gathering. The following table gives the average results from the data obtained.

TABLE OF TON -MILAGE.

Ton-milage per ton of motor.						Ditto per mule 1300 lb. mule		
Gasoline			Electric			Mule		
Net Coal	Net Car	Total	Net Coal	Net Car	Total	Net Coal	Net Car	Total
56.8	32.8	89.6	57.2	42.2	99.4	17.4	10.0	27.4

This table shows that the electric motor gives a slightly greater ton-milage than the gasoline motor. This may be due to the fact that the latter is newer and not so well understood and, therefore, it may be at a slight disadvantage owing to improper handling. The mule haulage data is taken from notes on gathering. No data could be obtained from mines where mules are used for main haulage.

This is probably due to the fact that a company which is so obsolete in its methods of mining coal as to use mules on the main haulage roads does not keep close tally on costs.

While these ton-milage figures show what the gasoline motor, electric motor and mule do under working conditions they do not give any comparison of costs of installation and operation, and to show this in a proper light I shall assume a mine in the same district and equip it with the different systems. Suppose this mine is 400 feet deep, has medium grades, (maximum grade not over 3%) has its parting 3000 feet from the shaft and the haulage road is equipped with 20 lb. rails. The mine cars used weigh 2000 lbs. net and have a capacity of $2\frac{1}{2}$ tons and the daily output of the mine is 2000 tons. The mine is equipped for mule haulage throughout and must have the rails replaced with heavier ones before any kind of mechanical haulage can be used. The following tables give the cost of installation of an electric haulage system, a gasoline haulage system and the cost of operation of these systems and also that of mule haulage. Operation costs are based on 200 working days per year.

A ton mile is defined as the amount of work expended in drawing 2,000# through a distance of one mile. Grades are not considered, but mines have been chosen which have similar grades.

COST OF ELECTRIC INSTALLATION.

1 - 150 Kw. generator and switchboard------------------$2100.

1 - 200 H.P. Engine 18 x 18-------------------------------- 2000.

Foundation and placing engine----------------------------- 300.

1 - 250 H.P. tubular boiler------------------------------- 2500.

3000 ft trolley wire-------------------------------------- 340.

800 ft. lead cable @ 55¢--------------------------------- 440.

225 trolley hangers @ 65¢-------------------------------- 146.25

260 bonds @ 35¢--- 91.00

25 cross bonds @ 35¢------------------------------------ 9.25

10 trolley frogs @ $2.75-------------------------------- 27.50

1 extra 250 armature---------------------------------- 375.00

2 motor jacks @ $12.80---------------------------------- 25.60

Extra fittings for motor---------------------------------- 75.00

40 ton 40 lb. rail @ $28,(credit 20 lb.) rail $1120---- 560.00

22 kegs 4½ x ½ spikes @ $3.75-------------------------- 82.50

16 split switches material and labor @ $17.00--------- 272.00

Fish plates and bolts------------------------------------ 95.00

Lumber for trolley supports----------------------------- 25.00

Sundries--- 50.00

Labor cost-- 2000.00

2 12-ton locomotives----------------------------------- 5000.00

$16,701.60

GASOLINE INSTALLATION.

```
2 - 12 ton motors-------------------------$9000.00

2 motor jacks @ $12.80--------------------'   25.60

Extra fittings for motors-----------------   75.00

40 tons 40 lb. rail $1120.
Credit  20 lb. rail   560.----------------  560.00

22 kegs 4½"x ½" spikes @ $3.75------------   82.50

16 split switches material and labor
                        @ $17.00------  272.00

Fish plates and bolts--------------------   95.00

Labor cost------------------------------- 1000.00

            Total------------------$11130.10
```

DAILY COST OF OPERATION GASOLINE.

200 working days per year.

```
Interest on investment $11130.10 @ 5%---------------$2.78

Depreciation and repairs 8%------------------------- 4.45

Fuel 40 gal. @ 15--------------------------------- 6.00

Oil and waste------------------------------------- .30.

2 locomotive runners @ $3.60---------------------- 6.40

Mechanician's salary-----$125.00 per month-------- 7.50

            Daily cost of operation-----------$27.43
            Cost per ton (2000 tons daily)------- .0137
```

DAILY COST OF ELECTRIC OPERATION.

200 working days per year.

Interest on investment $16701.60 @5%--------- $4.18

Depreciation and repairs 8%-------------------- 6.68

Fuel, 4 tons @ 75¢---------------------------- 3.00

Oil and waste--------------------------------- .30

2 locomotive runners @ $3.20------------------ 6.40

Electrician @ $125---------------------------- 7.50

1/2 fireman @ $2.00--------------------------- 1.00

Total--------------- $29.06

Cost per ton (2000 tons
daily)------   .0145

DAILY COST OF MULE HAULAGE.

200 working days.

Interest on investment 52 mules @ $200,
$10,400 @ 5%--------------$ 2.60

Depreciation 20%------------------------------ 10.40

Feed, shoeing, care @ 50¢--------------------- 26.00

17 drivers @ $2.82---------------------------- 47.94
Total----------------$ 86.94

Cost per ton (2000 tons
daily)----   .0435

BASIS FOR CHOOSING SIZE OF MOTORS AND NUMBER OF MULES.

2000 tons hauled 3000 feet in 2000# cars = 2080 ton miles.

Gasoline motor hauls 89.6 ton miles per ton of motor in 8 hours.

Electric motor hauls 99.4 ton miles per ton of motor in 8 hours.

Mule hauls 27.4 according to table, but this is low on account

of the fact that this is gathering data.   A mule is allowed 40

ton miles, therefore,

$$\frac{2080}{59.6} = 23.2 \text{ ton of motor--allow 2-12 ton locomotives.}$$

$$\frac{2080}{99.4} = 22.1 \quad " \quad " \quad " \quad " \quad 2\text{-}12 \quad " \quad "$$

$$\frac{2080}{40} = 52\text{--Number of mules required.}$$

These figures show that for a mine of this output there is

very little difference between the cost of electric and gasoline

haulage and that mules cannot compete with either.   In fact it

would be impossible to reach this tonnage output with mule haul-

age because so many mules would be required to draw the coal that

there would be no room in the mine for anything but the mules.

CHAPTER IV.

THE PEABODY MINE.

The Peabody mine, located five miles west of Springfield, Illinois, has installed gasoline motors in order to increase the output. Five string teams of three mules each had been employed to do the main hauling. The partings were pretty well back and it was impossible to get out much over 1500 tons daily with the mules. Increasing the number of mules would have the evil effect of crowding the haulage roads and instead of increasing the output would merely increase the fixed charges. The company, therefore, turned to some form of mechanical haulage and since the mine was small they thought gasoline motors would pay better than an electric haulage system. They have been using a ten ton Whitcomb motor for two years and about nine months ago purchased another motor, weighing twelve tons, from the same Company. They have increased their output to about 2500 tons and sometimes run over 3000 tons in 8 hours. It is needless to say that they are well pleased with the gasoline motors.

The following table shows the relative cost of the two means of haulage at the Peabody mine.

COST OF INSTALLATION OF GASOLINE HAULAGE SYSTEM.

```
One 10 and one 12 ton  gasoline motor-----------$9000.00
2 motor jacks @ $12.80---------------------------   25.60
Extra fittings for motor-------------------------   50.00
75 tons 35 lbs. rails @ $28, $2100.
        Credit 20 lb. rail------ 1200-------------  900.00
45 kegs 4½" x ½" spikes @ $3.75------------------  168.75
12 switches, material and labor @ $17.00--------  204.00
Fish plates and bolts---------------------------  195.00
Labor------------------------------------------- 1500.00
                     Total----------------------$11843.35
```

COST OF DAILY OPERATION.

200 working days.

Interest on investment $11843.35 @ 5%---------------$2.96

Depreciation and repairs 8%--------------------------- 4.73

Fuel 40 gals. @ 15¢--------------------------------- 6.00

Oil and waste--------------------------------------- .30

2 locomotive runners @ $3.50----------------------- 7.00

Mechanician's salary $125 per month---------------- 7.50

Total daily cost----------$28.49

Cost per ton (2500 ton daily)------------ .0114

COST OF DAILY OPERATION OF MULE HAULAGE.

200 working days.

Interest on investment 15 mules at $200,
              $3000 @ 5%------------------$ .75

Depreciation 20%------------------------------ 3.00

Feed, shoeing, harness, care @ 65¢----------- 9.75

5 drivers @ $2.84--------------------------- 14.20

Total daily cost---------------------------$27.70

Cost per ten (1500 tons daily)----- .0185

These costs show that the gasoline motors are getting the coal
cut for ·71¢ per ton cheaper than the mules, or at a saving of 39% on haulage
charges. The motor must also be given credit for increasing the
output of the mine from 1500 to 2500 tons daily, which was impossible
with mule haulage.

The photographs shown below were taken in the Peabody mine and
show one of the gathering mules, and the twelve ton Whitcomb gasoline
motor attached to its loaded trip.
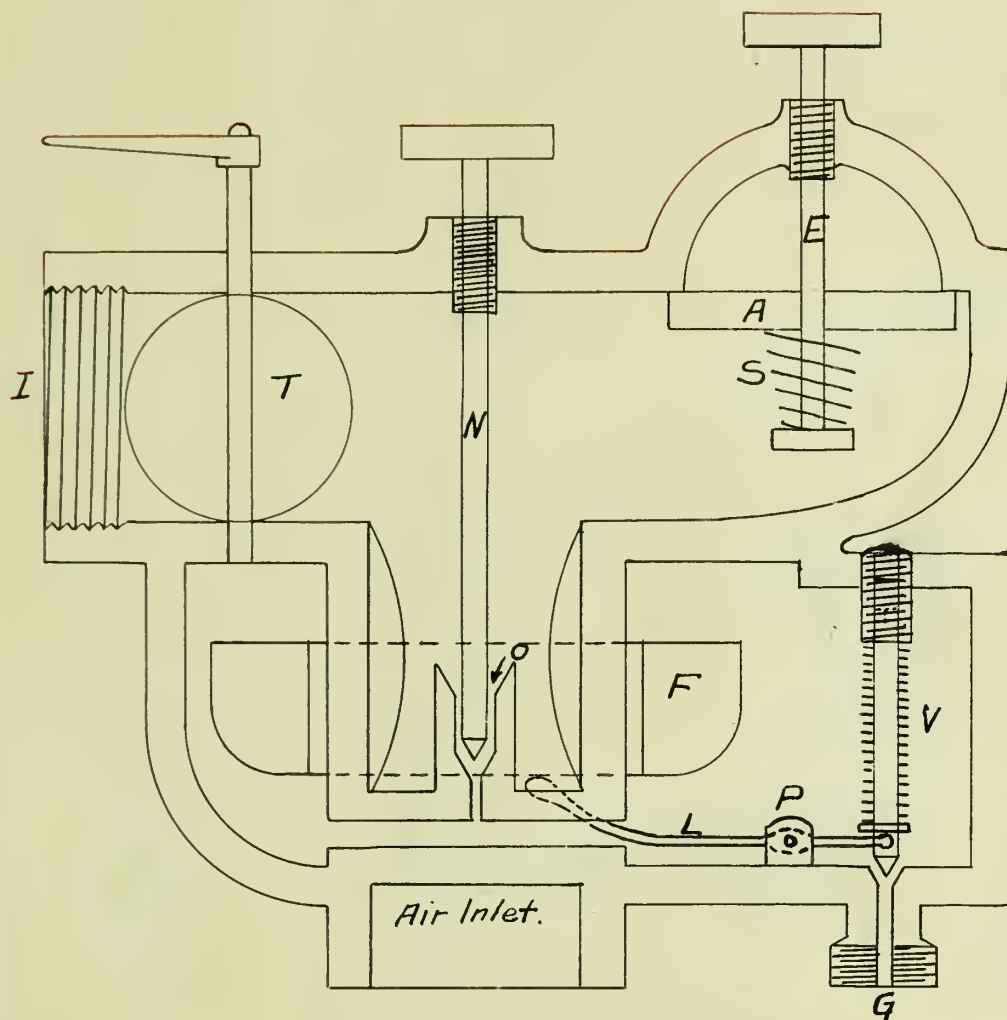
Skingston Float-feed Carburetor.

This twelve ton locomotive stands 42 inches above the rail, is 56 inches wide on a 42 inch gauge track and is about 14 feet long. Its draw bar pull is rated at 4800 lbs. and its motor is large enough to slip the wheels on a dry sanded track.

The engine is a 4 cycle, 4 cylinder, double opposed with 7" x 8" cylinders and dual system of ignition. It is equipped with an Eisemann magneto and a Skingston carburetor and is capable of developing 100 horse power.

A skilled mechanic is employed to look after the two locomotives and keep them in running order. His salary is $125 per month and the Company considers him well worth the money. In the two years that they have used the gasoline motors they have had no cause for complaint of any kind. The fumes from the machines have not brought forth any objections from the miners nor from any one connected with the mine. The motors work on the return current only and are not used for gathering.

THE SKINGSTON CARBURETOR.

The drawing on the preceding page is a cross section of the Skingston central flow float-feed carburetor. It is lettered and in describing it I shall refer to parts by letters. The carburetor is of the float feed type, that is, the flow of fuel into the vaporizing chamber is regulated by a float, lettered F. This float is shaped like an annular ring and floats freely just above the long end of a lever, L, which is pivoted at P. The short end of this lever is forked and rests under the projection on the fuel valve V. The fuel enters at G and flows out through the small openings to the outlet O, where it is picked up by the current of air entering at A.

The throttle T is a disc regulated by a short lever. At A is a flat auxiliary air valve held in place by the spiral spring S, which admits more air as needed.   In operation as the fuel is used up the level falls in the fuel chamber, allowing the float to settle and finally by its weight press down the end of the lever L.   This raises the valve V and allows fuel to enter and raise the level in the float chamber, lifting the float clear of the lever and allowing the valve V to settle by its own weight aided by a small spiral spring, closing the fuel port.   The fuel flow is regulated by the needle valve N.   It is found that if the fuel supply is regulated for slow speed the increased suction at high speed will draw in an undue amount of fuel, making the mixture too rich.   For this reason the auxiliary air valve A is fitted; it is so adjusted that the increased suction at high speed will draw it from its seat and admit a certain amount of pure air to dilute the mixture to the proper point.   The amount of air admitted by the auxiliary air valve may be regulated by changing the tension on the spring S, by means of the threaded spindle E.   Increasing the tension on the spring will decrease the lift of the valve, and consequently decrease the amount of air admitted, or vice versa.   It will be noticed that the air passage is contracted opposite the opening O; this is for the purpose of reducing the area of the passage and increasing the velocity of the air current, thus making the action of the carbureter more positive at low speed.   The carbureter is secured to the engine by the threaded end I.
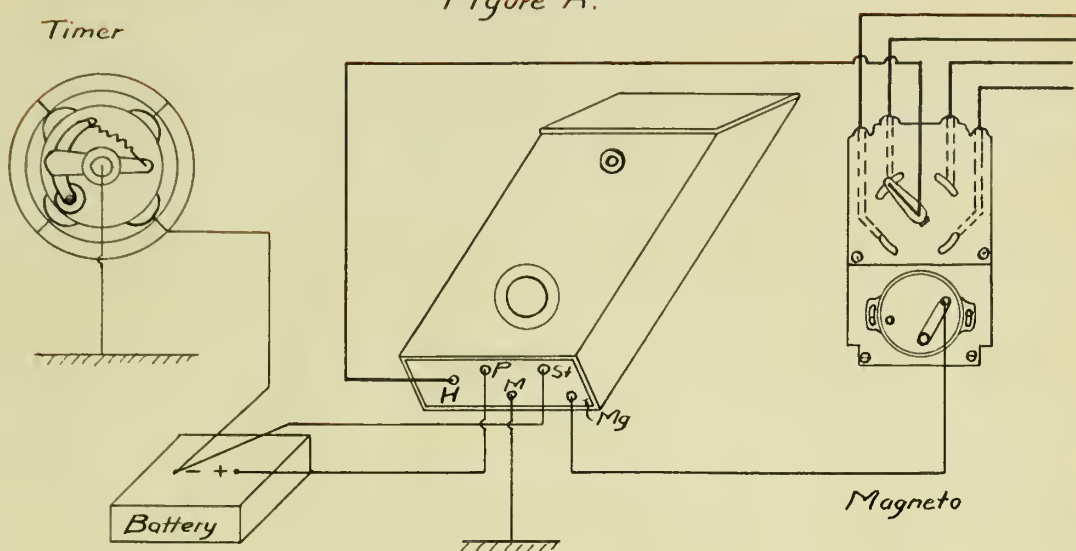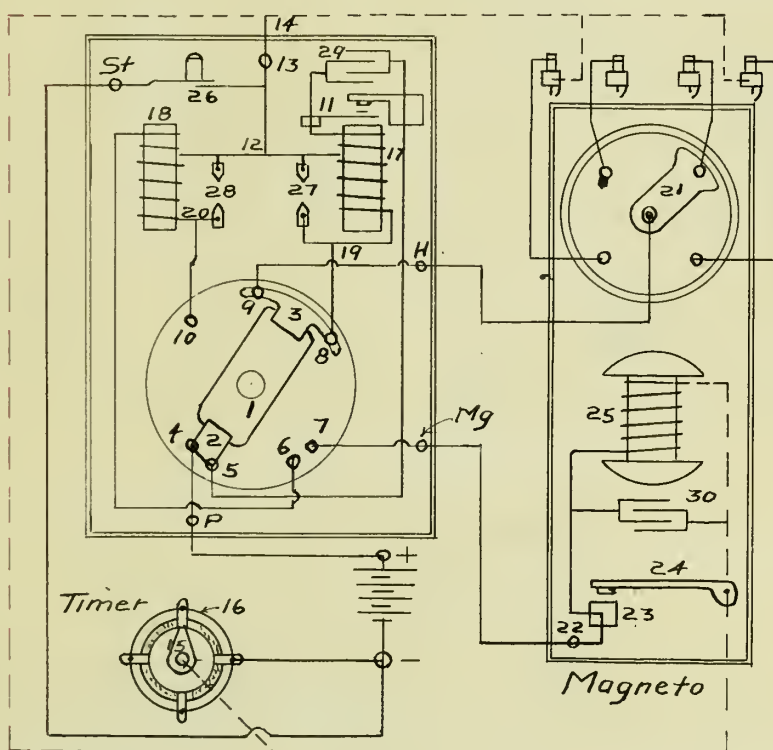
Figure A.

Timer

P
M
St
H
Mg

Battery

Magneto

Figure B

St
26
13
14
29
11
18
12
17
28
27
20
19
H
10
9
3
8
1
4
2
5
6
7
Mg
P

21

25
30
24
23
22

Timer
16
15

Magneto

Eisemann Ignition System.

THE EISEMANN IGNITION SYSTEM.

The preceding drawings illustrate the various parts of the Eisemann high tension dual ignition system. In this system the battery has its own timer and trembler spark-coil, and the magneto has its own mechanically operated interrupter and a non-trembler spark-coil. The same distributer is always used for directing the high tension current to the spark plugs. The two spark-coils are enclosed in the same box, which has a hand switch for throwing in either the battery or the magneto, or for cutting both out of circuit.

The movable part of the switch is represented conventionally, in figure B, as a piece of insulating material 1, to whose ends are fastened two metal contact-pieces 2 and 3. The stationary contact-points of the switch are 4 and 5 for the battery circuit, 6 and 7 for the magneto circuit, and 8, 9 and 10 for the high tension circuits. The timer is of the form common to battery ignition systems with individual spark-coils of the trembler type, but is modified by connecting all of the stationary contact-points together with a wire 16.

The switch is shown set for using battery current. The path of the current is from the positive side of the battery to the terminal P and switch pole 4, through 2 to 5, then to the trembler interrupter 11 and primary winding of transformer 17 from which it flows to ground by the path 12-13-14. This brings it to the rotor 15 of the timer, from which it goes to the negative side of the battery. The high tension current follows the path from the secondary terminal 19 to the switch-pole 9, then to terminal H and on to the

rotor 21 of the distributer, which directs it to the spark-plugs. From the ground side of the spark-plug the high tension current has the permanent circuit 14-13-12 back to the spark coil 17.

When the switch is set to the position for magneto current, the part 2 connects the poles 6 and 7, and the part 3 connects poles 9 and 10. The magneto is of the interrupted shunt-circuit type. During the time the interrupter parts 23 and 24 are in contact with each other (interrupter closed) most of the armature current flows from 23 through the interrupter lever 24 to ground and then to the grounded end of the armature winding 25. A small portion of the armature current flows at the same time from 23 through the path 22-M G to the switch-pole 7, then through 2 to 6 and on to the non-trembler transformer 18, through whose primary winding it flows, and then to ground by path 12-13-14. This brings it to the grounded end of the armature winding. At the instant the shunt circuit is broken by the interrupter of the magneto, a comparatively large current is sent through the transformer circuit just followed out, and a spark is caused to jump at one of the spark plugs. The high tension current goes from the secondary terminal 20 to switch-pole 10, then through the metal 3 on the switch-bar to pole 9 and on to the rotor 21 of the distributer. The push-button 26 is for starting the motor on spark. The switch must be set in battery position, as shown, when doing this, and the timer rotor must not be in contact with any of the stationary contacts of the timer. Pressing the push-button then closes the battery circuit through the trembler coil 17. If the rotor of the timer is in contact with one of the stationary

contact-pieces of the timer while the motor is standing still, the battery switch is then closed through the trembler coil when the switch is in position as shown. The safety spark-gap 27 is for protecting the trembling coil 17, and the safety-gap 28 answers the same purpose for coil 18. The condenser 29 is in parallel with the trembler interrupter 11, and condenser 30 is in parallel with the interrupter 23-24 of the magneto. The rotor of the timer and then interrupter of the magneto must be set so that the instant of ignition will not be greatly changed by switching from one source of primary current to the other.

TRANSMISSION.

The transmission provides for two speeds both forward and reverse; a low starting speed of about nine miles per hour and a high speed for long runs of about 18 miles per hour. All gears are of steel, cut and hardened. Change of direction and speed are made by clutches and not by shifting gears.

CLUTCHES.

There are two sets of clutches used--one set for forward and reverse motion, and the other set for shifting from high to low speed. The latter is of the jaw clutch type.

There is an interlocking system between the two sets of clutches so that the jaw clutches cannot be thrown from one speed to the other, except when the forward and reverse clutches are both thrown out and are in a neutral position; therefore there is no jar or strain when the jaw clutches are shifted. These two

sets of clutches are controlled by two straight levers; both sets of clutches run within the transmission case and are kept flooded with oil by means of an oil circulating pump. Ball thrust bearings are provided at all necessary points.

DRIVE.

The drive from the transmission shaft to the front axle is by means of a double chain. The front and rear axles are connected by a single chain. The four wheels are therefore connected so as to give the maximum tractive effort.

COOLING SYSTEM.

The engine is cooled by having water circulate around the cylinders. The automobile type of radiator cannot be used for rough mining use, so heavy cast iron tanks are used instead. These tanks are of the condenser type and give very high efficiency. The circulating pump for forcing the water through the system is driven by forged steel cut gears directly from the main shaft. Air is forced through the cooling tanks by a fan fitted on the main driving shaft.

GASOLINE TANKS.

The gasoline tanks are constructed so that no gasoline can be put into or taken out of them except through the pipes leading to the engine, when they are on the motor. They are connected to the motor frame by means of a large swivel nut, and after they are connected a valve in the tank is opened, admitting the gasoline to the engine. There is also a valve in the pipe system between each tank and the engine, so that there is a double shut-

off for each tank, one in the tank and one in the pipe line. The capacity of each tank is about five gallons. Provision is made for two tanks, one on each side of the motor, and when in place they are within the walls of the motor and covered over with a cast iron door, so that it is well-nigh impossible to hit or injure them.

In operation two filled tanks are put on the motor, while the other two tanks are sent outside the mine to be filled; four tanks are furnished with each motor. When the tanks on the motor are nearly empty these filled tanks are sent in and are put on the machine and the empty tanks sent out. In making change of tanks the valves in the tanks and in the **pipe** lines are shut off so that no gasoline is exposed in making the change, and change can be made in the presence of a miner's naked lamp without danger of explosion.

GERMAN LOCOMOTIVES.

At the present time there are in the neighborhood of 2000
gasoline mine locomotives in use in European countries.   These
locomotives are of German type and differ from American gasoline
mine motors in engine design.   A single cylinder, four-cycle,
horizontal engine is used and is run at a low speed.   It uses
either alcohol, gasoline, naptha or gasoline for fuel, but naptha
and gasoline are more commonly used.   The exhaust gases are
sprayed with water in the exhaust box before they are emitted to
the mine air.   This has the effect of cooling, condensing, and
rendering them harmless to the health of the mine workers and al-
so prevents any liability of the exhaust gases to ignite mine gas
and thereby cause an explosion.   These locomotives are used in
mines where methane is continually present and are considered to
be perfectly safe by mine inspectors of the Austrian, French and
German Governments.

The fuel tank on the locomotive has a capacity of ten gal-
lons.   A 12-H.P. locomotive uses six gallons of gasoline per shift
of ten hours. The fuel tank is made perfectly tight and is placed
beside the water tank.   The former is filled at the end of each
shift outside the mine.   The locomotive is mounted on four driv-
ing wheels which are connected and driven in tandem.   Change of
speed is made by means of clutches and not by shifting gears.
Brakes are applied by means of a screw and lever.   The locomo-
tive is equipped with the usual line of sandboxes, headlights,
warning bells, etc.   These locomotive are considered entirely sat-
isfactory by the Germans and other Europeans and they submit costs
of about 1.2¢ per ton-mile after 20% depreciation has been included.

CHAPTER V.

ADVANTAGE AND DISADVANTAGE OF THE VARIOUS
FORMS OF MECHANICAL HAULAGE.

The steam locomotive for mine work is limited to open mines, or drifts, where the engine can work outside part of the time. Its chief advantage lies in cheapness of operation and low cost of installation. It should not be used in closed mine work on account of the vitiating fumes and gases discharged from the stack and for this reason it is not used a great deal for mine haulage.

The compressed air locomotive, on the other hand, improves the ventilation instead of injuring the air which the miners must breathe. They are absolutely safe in gaseous mines as there is no flame or **spark** to ignite **explosive** mixtures. They are probably more easily and more cheaply kept in repair than any other mine locomotives and their operation requires no greater, if as great, skill as an electric or steam locomotive. The cost of installation of a compressed air haulage system may be greater or less than that of an electric system, depending upon the local conditions. Mr. Hodges, in an article appearing in Coal Age, Feb. 3, 1912, claims that the costs of electric and compressed air haulage vary but little and that for gathering purposes the mule is a close competitor of both. As a general rule compressed air haulage is not considered as cheap as that of electric haulage but many of the opinions expressed in regard to the relative economy of the two systems are founded largely upon prejudice, with little or no basis of accurate information. Although compressed

air locomotives have not been used in Illinois coal fields they are used extensively in the eastern fields and also in many of the western ore mines.

One of the most important matters for consideration in mine haulage is the transmission of power. When compressed air is transmitted over long distances a great deal of power is lost, due to leaks and to   fall   in temperature. Electric power can be transmitted over the same distances with comparatively no loss and for this reason electric haulage systems can show a higher efficiency than the compressed air. The disadvantages of the electric system are that a trolley wire or other suitable conductor must be installed, the rails must be bonded and cross-bonded for the return circuit, the electric locomotive cannot leave the trolley line, except when equipped with a gathering reel which is more or less trouble, and the danger to men and animals in the mine from the live conductor. Electric locomotive systems are used very extensively in Illinois and are considered a very cheap means of haulage. A mine of small output cannot afford to use them because of the high cost of installing a   system of this kind.

Where mines have outgrown a mule haulage system it may be found very satisfactory to install gasoline motors. Gasoline motors alone cost more than electric motors, but the former are complete in themselves and have the advantage over the latter in that no conductor need be installed; rails need not be bonded, nor is it necessary to install an expensive generating plant. Where the output of a mine ranges from 500 to 2000 tons daily this is of great importance. Then, too, the life of a mine might not justify

as great an expenditure of capital as the installation of an elec-
tric haulage system calls for. The gasoline motor gives just as
good satisfaction as an electric motor; its fumes are not injurious
to miners providing 100 cu. ft. of air per minute be provided for
each ton of motor; it is not dangerous in slightly gaseous mines,
and it is not restricted to certain tracks on account of a trolley
wire.

In regard to the effect of combustion on the mine air, the
Whitcomb Company state that they have a number of chemical analy-
ses made of the mine air where motors have been used and if the
motor is properly operated and there is a fair current passing
through the entries the exhaust will have no effect upon the health
of the men. The volume of exhaust from these motors will vary from
in the neighborhood of 100 cubic feet per minute on a four ton
machine up to 300 or 400 cubic feet per minute on a 16 ton machine.
The only gases in the exhaust that will have an effect on the men
are carbon dioxide and carbon monoxide. If the engine is properly
adjusted there is only a small fraction of a per cent of carbon
monoxide which is the really dangerous element, while there may be
as high as 4 to 6% of carbon dioxide. (This statement is supported
by chemical analyses made by the Whitcomb Company.) Assume for
sake of example that as much as 1% of carbon monoxide and 6% of
carbon dioxide are present, which would indeed be the worst possible
condition . On a 4 ton machine there would then be about one cubic
foot of carbon monoxide and six cubic feet of carbon dioxide. Now
1/10 of one per cent of carbon monoxide is dangerous in mine air,
while as much as 2% of carbon dioxide can be present without being

injurious to the health of the miners. Therefore, to be within
safe limits, the one cubic foot of carbon monoxide would have to
be diluted in 1000 cubic feet of fresh air, or in other words,
there should be at least 250 cubic feet of air per minute for each
ton of motor. The Whitcomb Company recommend 1000 cubic feet of
air per ton of motor and under these conditions it would be im-
possible to detect carbon monoxide even by aid of chemical analy-
sis. In any mine that is large enough to require the services of
a motor, the law would require more air than that. The law requires
100 cubic feet of air per minute for each man and 500 cubic feet
per minute for each animal. It is very seldom that a motor is put
in a mine that is not handling 250 or 300 tons per day, and ordi-
narily the average tonnage handled by the men employed will not
exceed 5 tons. Therefore, if they have to turn out 300 tons per
day, ordinarily they would have 60 men employed in some capacity
about the mine, and should have to provide 6000 cubic feet of air
per minute and the chances are that for gathering purposes they would have
six or eight mules, which would require another 3000 or 4000 cubic
feet. Under usual working conditions a 4 ton motor would handle
all the coal in a mine of this sort, and that would allow from 1500
to 2500 cubic feet of air per ton of motor. The only problem of
the ventilation is to keep the motors operating in an entry where
there is an air circulation and where the exhaust from the motor
does not have a chance to accumulate at any one point.

No accurate data can be obtained in regard to the danger of
exploding gas with a gasoline motor. The Whitcomb Company state
that they have quite a number of motors operating in mines that
are quite gaseous and the motors are working on the return airways

where they would come in contact with the gas if any were present,
and no explosions have been caused by these motors. About the
only thing that would cause a gasoline motor to ignite gas would
be to have one cylinder missing fire; that is, not exploding its
charge, have this charge get into to muffler or exhaust pipes, and
then become ignited from the exhaust of another cylinder. A con-
dition of this sort is very noticeable on an engine and should be
corrected at once on account of the loss of power, even though
there were no danger from explosion of gas. With one cylinder
missing fire it is seldom that the charge is ignited from the ex-
haust from the other cylinder owing to the fact that it passes out
of the exhaust pipes before the charge of the missing cylinder
enters the exhaust pipes. Before reaching the atmosphere the ex-
haust goes out through a muffler and in case of a very gaseous mine
the exhaust could then be carried up through the water boxes and
passed through a water spray. This latter practice is not recom-
mended unless absolutely necessary as it has a tendency to heat
up the circulating water and requires same to be supplemented more
often than otherwise.

CHAPTER VI.

C O N C L U S I O N.

Technical papers from time to time publish statements that it costs so many cents, or fractions thereof, per ton-mile to haul coal with mules, steam, compressed air and electric locomotives. Up to the present time little has been said in this line concerning gasoline locomotives due to the fact that gasoline mine motors are of comparative recent origin.

In choosing a form of haulage for a mine there are many conditions that must be considered before any sensible conclusion can be formed. The kind of power adopted and the particular system of haulage depend, in a great measure, on local conditions, such as the quality and kind of material mined, the distance it must be transported, the presence--or absence--of explosive gases in mines and whether the haulage ways are intake or return air-ways, the conditions of the tracks, including such items as grade, curves, lengths, future extensions, the size of mine cars and dimensions of haulage roads, also whether the mine is dry or wet, and many other considerations. The cost of installation and operation of the different systems should be compared with each other, also the probable life of the mine and the cost of future extensions. The conditions that enter into the choice of a haulage system are so numerous that only the most general rules can be given in stating the advantages and disadvantages of the different systems. All local conditions which have an influence on the successful operation of haulage should be investigated and given proper weight.

No haulage system is suitable for all localities and each type has peculiarities that are better adapted to one place than another.

The use of mules in mine haulage is generally restricted to short hauls on main haulage roads and to gethering loaded cars and distributing empties to the rooms. No fixed rule can be laid down for the distance to which mule haulage can be economically extended but it is generally considered that one half mile is as far as efficiency and economy will permit and perhaps that distance is too great if the output of the mine is much over 1000 tons daily.

When we turn to mechanical haulage we must remember that dividends will result only from proper care of our system. In order to secure all of the advantages to be derived from locomotive haulage it is necessary to arrange the mine tracks, partings, and switches so that cars may be handled in either direction without delay. For underground locomotive haulage, proper construction and alignment of tracks are more important than for surface locomotive haulage because a wreck or even a derailment in the mine usually stops the whole haulage system and the mine work as well, since there is generally no room to lift the locomotive off the track and set it to one side so that other locomotives, if available, may take care of the haulage, nor can temporary tracks be laid alongside of the wreck. A soft muddy roadbed, light rails, ties too small or placed too far apart, and fish-plates too small or carelessly put in, will neutralize the economies of the most carefully designed and expensive equipment. Frogs and switches should be carefully constructed, and turnouts should be easy and gradual, in order that neither cars nor locomotives may be derailed. The

roadbed should be firm and solid. If there is a fireclay bottom keep it dry. **Ties** should be not less than 6 inches wide and 6 inches thick, and wider ties are better. They should be placed so that there is not over 12 inches between them, and the rails should be firmly spiked to them. Splice-bars or fish-plates should be firmly bolted to the rails. Toe plates and guide rails are invaluable on curves. Rails should be laid accurately to gauge, with proper allowance on curves. The weight of the rail for locomotive haulage should not be less than 40 lbs. to the yard on main haulways. Locomotive tires wear badly when the rails are narrow, and this wear is particularly noticeable on grades and where the tracks must be sanded, as, for instance, at the partings where the trains are started. In order to give additional surface contact for the wheels at partings and on grades, the loaded track is sometimes laid with 60 lb. rails, while a 40 lb. rail is used on other parts of the roadway. A dirty and greasy track allows the wheel to slip and the draw-bar pull of the locomotive is greatly reduced. It is, therefore, very desirable that the track be not only well laid, but that it be kept in good condition in order that good results be obtained from the locomotives. As the hauling power of a locomotive is greatly reduced when it hauls up-hill, the grades of the mine tracks should be such that the locomotives may not be at a disadvantage.

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